The In-Medium Behaviour of Finite Width Charmonia

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Question:
How to calculate quarkonium dissociation points?

Two possibilities:

- **Schrödinger equation with temperature-dependent heavy quark potential** $V(r, T)$
- **quarkonium spectrum from finite** T **lattice QCD**

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- Schrödinger equation with temperature-dependent heavy quark potential $V(r, T)$
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Both have intrinsic problems

- survival in potential theory for radii $r \geq 1/T$, binding energies $\Delta E \leq T$: what does that mean?
- spectral functions via MEM from correlator calculations, correlator ratios vs. reconstructed "vacuum" form: how much freedom?

1. MEM Studies of In-Medium Charmonium Survival

quenched: Umeda et al. 01,...; Asakawa & Hatsuda 04; Datta et al. 04,...; Iida et al. 05; Jakovac et al. 05; unquenched: Aarts et al. 05,...

Correlation function $G_i(\tau, T)$ for mesonic quantum number channel i, spectral distribution $\sigma_i(\omega, T)$

$$G(\tau, T) = \int d\omega \ \sigma_i(\omega, T) \ K(\omega, \tau, T)$$

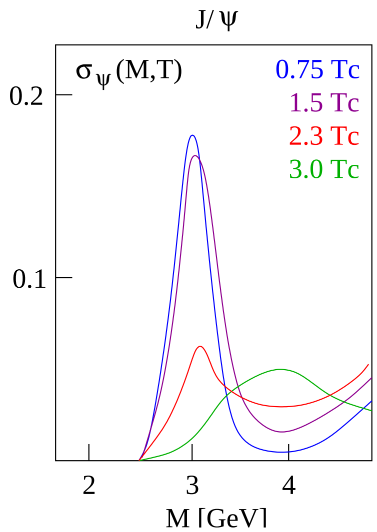
with kernel

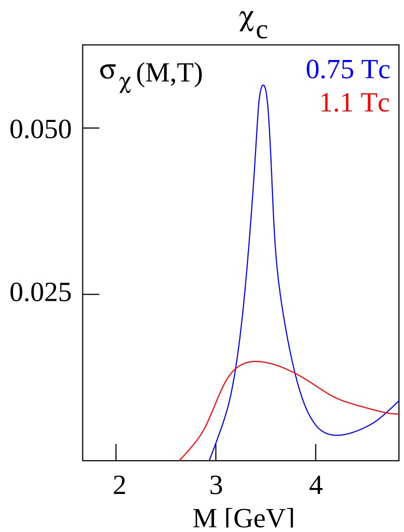
$$K(\omega, \tau, T) = \frac{\cosh[\omega(\tau - (1/2T))]}{\sinh(\omega/2T)}$$

relates imaginary time τ and $c\bar{c}$ energy ω; invert $G(\tau, T)$ by MEM to get $\sigma(\omega, T)$:

- quenched and unquenched ($N_f = 2$) QCD agree schematic pattern

lattice resolution limits precision; reliable only for peak strength & position, not widths & continuum





charmonia

χ_c is dissociated for $T \geq 1.1\ T_c$

J/ψ persists up to $1.5\ T_c < T < 2.3\ T_c$

(in accord with U-based potential model studies)

- caveat: finite T widths, what can MEM detect?

report here on an attempt to address this problem
H.-T. Ding, O. Kaczmarek, F. Karsch, HS (in preparation)

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2. Model Spectral Functions

"non-MEM" correlator study of charmonia in hot QGP:

compare correlator $G(\tau, T)$ for $T > T_c$
to a reference correlator $G_0(\tau, T)$
using spectral function at $T \ll T_c$ (ideally $T = 0$)

$$G_0(\tau, T) = \int d\omega \; \sigma_i(\omega, T = 0) \; K(\omega, \tau, T)$$

shows how correlator would look if spectrum at $T > T_c$ were same as at $T = 0$

ratio $R(\tau, T) = G(\tau, T)/G_0(\tau, T)$
indicates finite temperature modifications of spectrum

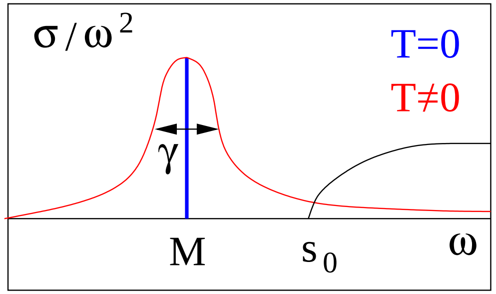
idealized spectrum at $T = 0$ (no zero point mode)

$$\sigma(\omega, T=0) = f\ \delta(\omega - M) + c\ \theta(\omega - s_0)\omega^2\sqrt{1-(\omega/s_0)^2}$$

$f \sim$ strength of resonance

$c \sim$ strength of continuum

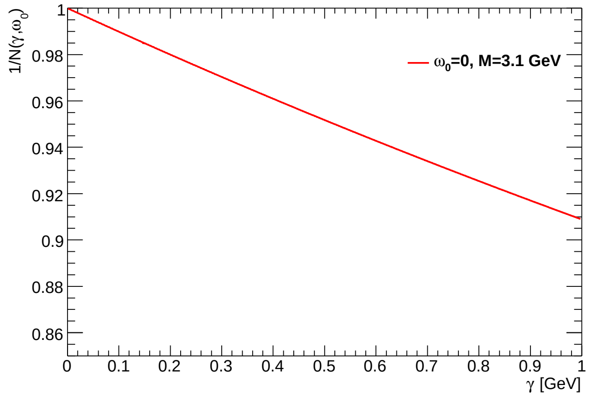
$s_0(T)$ continuum threshold



assume that at $T > 0$ resonance broadens (relativistic B-W), but retains same strength

$$\sigma_r(\omega, T) = N(\gamma)\ f\ \frac{M}{\pi}\left\{\frac{2\omega\gamma}{\omega^2\gamma^2 + (\omega^2 - M^2)^2}\right\}$$

$N(\gamma)$ assures normalization for width $\gamma = \gamma(T)$



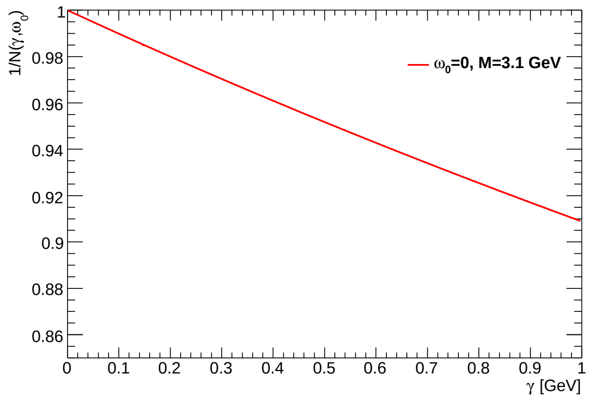
1/N(γ,ω0)
ω0=0, M=3.1 GeV
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
γ [GeV]

calculate correlator ratio

$R(\tau, T) = G(\tau, T)/G_0(\tau, T)$

to see what one can see

for different constellations



calculate correlator ratio
$\boldsymbol{R(\tau, T) = G(\tau, T)/G_0(\tau, T)}$
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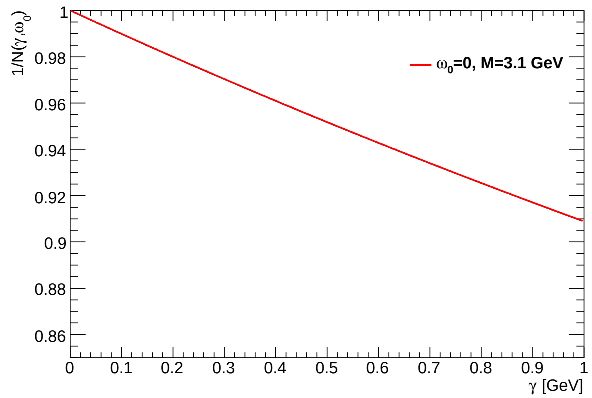
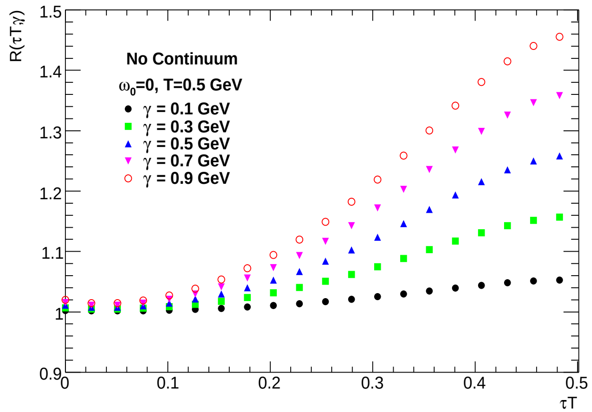


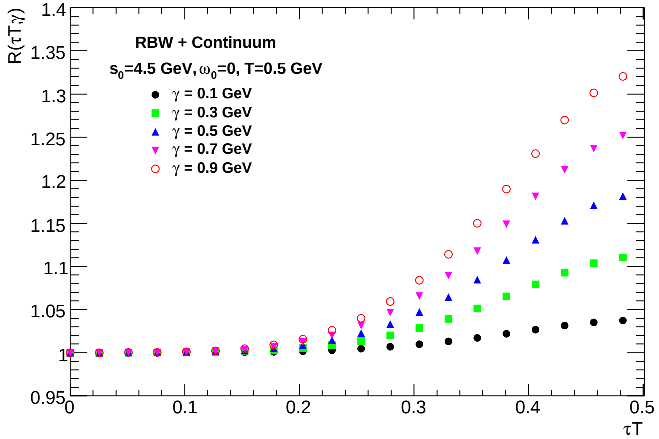
RBW resonance only,
no continuum;

NB: here $\boldsymbol{T = 0.5}$ GeV;
changing $\boldsymbol{T}$ at fixed $\boldsymbol{\gamma}$
has little effect



include *T*-independent continuum

reduces modifications due to finite width



include $\boldsymbol{T}$-independent continuum

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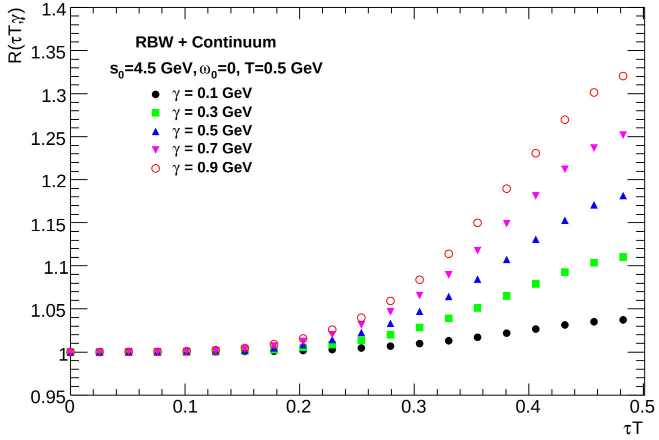
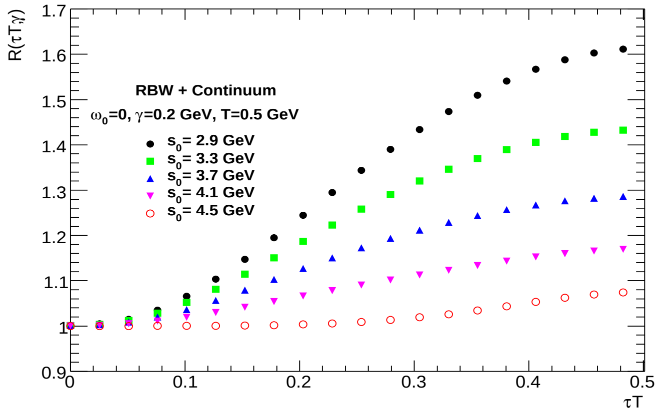


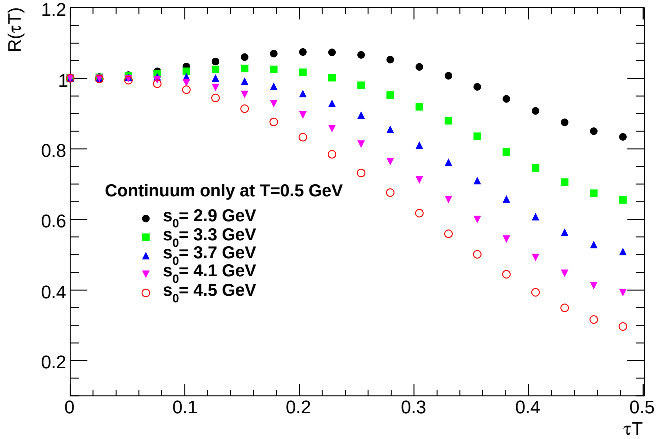
decrease continuum threshold

stronger change



remove resonance at finite T:

decreasing ratio



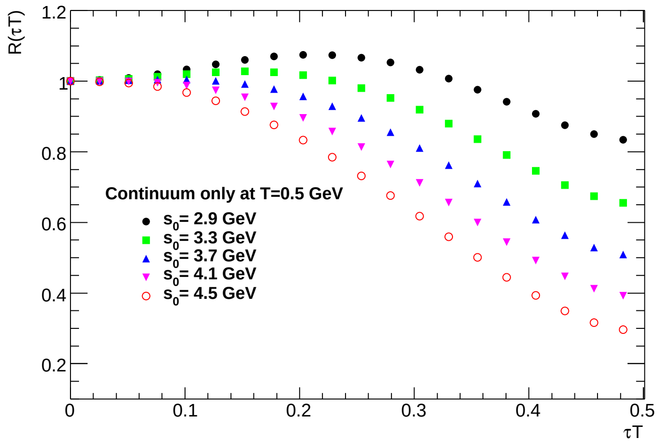
NB:

lowering continuum threshold simulates resonance

[Mocsy & Petreczky 2006]

remove resonance at finite T:

decreasing ratio



NB:
lowering continuum threshold simulates resonance

[Mocsy & Petreczky 2006]

by tuning resonance width and continuum threshold, could get

$$R(\tau, T) = G(\tau, T)/G_0(\tau, T) \simeq 1$$

for $\sigma(\omega, T) \neq \sigma(\omega, T = 0)$

Basic Problem

- $G(\tau, T)/G_0(\tau, T) = 1 \ \forall \ \tau$ has unique solution:

[Baym & Mermin]

$$\sigma(\omega, T) = \sigma(\omega, T = 0)$$

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- given $G(\tau, T)/G_0(\tau, T) = 1$ for N points $\tau_i, i = 1, ..., N$

or more precisely,

- given $G(\tau, T)/G_0(\tau, T) = 1 \pm \epsilon$ for N points τ_i, $i = 1, ..., N$

how to define "the best solution"?

back to MEM....

Conclusions

- resonance width and continuum threshold have clearly visible effects on correlator ratios
- resonance broadening leads to increase at large τ, due to low ω tail of RBW; shifting continuum threshold down enhances this
- resonance melting leads to decrease at large τ, due to less contribution at low ω; shifting continuum threshold down partially compensates this
- eventually compare to more precise correlator studies to model vector (J/ψ) and scalar (χ_c) channels